

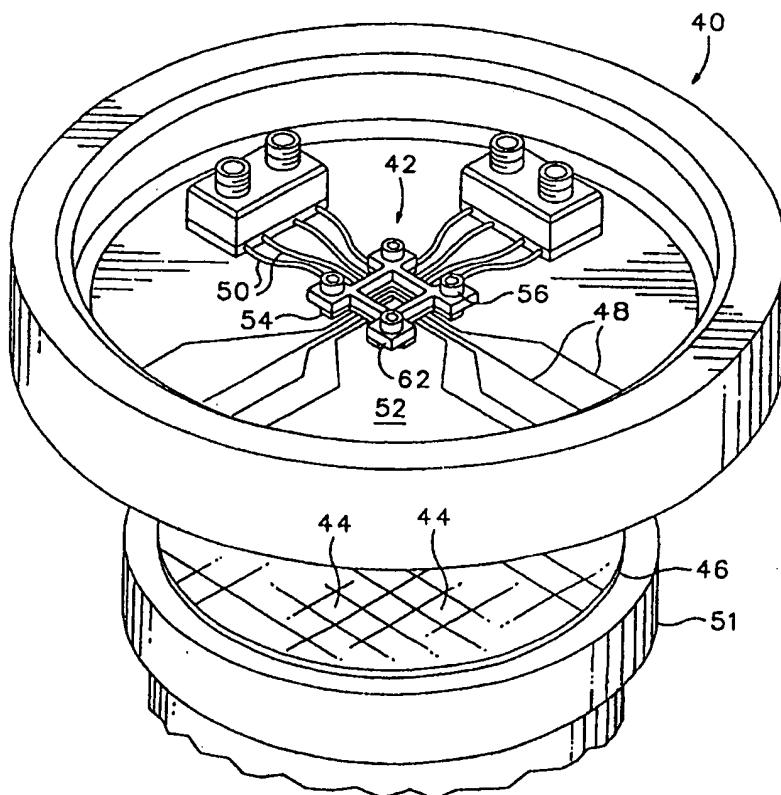


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US97/08292  <b>(22) International Filing Date:</b> 2 May 1997 (02.05.97)  <b>(30) Priority Data:</b> 08/695,077                      8 August 1996 (08.08.96)                      US  <b>(71) Applicant (for all designated States except US):</b> CASCADE MICROTECH, INC. [US/US]; 14255 S.W. Brigadoon Court, Beaverton, OR 97005 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> GLEASON, K., Reed [US/US]; 9615 N.W. Skyline Boulevard, Portland, OR 97231 (US). SMITH, Kenneth, A. [US/US]; 7245 S.W. Ashdale, Portland, OR 97223 (US). BAYNE, Mike [US/US]; 11505 N.E. 4th Plain Road #F-1136, Vancouver, WA 98662 (US).  <b>(74) Agents:</b> RUSSELL, Kevin, L. et al.; Chernoff, Vilhauer, McClung & Stenzel, Suite 600, One S.W. Columbia, Portland, OR 97258 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments:</i>

**(54) Title:** MEMBRANE PROBING SYSTEM WITH LOCAL CONTACT SCRUB**(57) Abstract**

A membrane probing assembly (42) includes a support element (54) having an incompressible forward support (66) tiltably coupled to a rearward base and a membrane assembly (72) with its central region (80) interconnected to the support (54) by an elastomeric layer (98). Flexible traces form data/signal lines (76) to contact (88) on the central region (80). Each contact (88) comprises a rigid beam (90) and a bump (92) located in off-centered location on the beam (90), which bump (92) includes a contacting portion (93). After initial touchdown of these contacting portions (93), further overtravel of the pads (100) causes each beam (90) to independently tilt locally so that different portions of each beam (90) move different distances relative to the support (54) thus driving each contact into lateral scrubbing movement across the pad (100) thereby clearing away oxide buildup. The elastomeric member backed by the incompressible support ensures sufficient scrub pressure and reliable tilt recovery of each contact (88) without mechanical straining of the beam (90).



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MEMBRANE PROBING SYSTEM WITH  
LOCAL CONTACT SCRUB

TECHNICAL FIELD

5           The present invention relates to probe  
assemblies of the type commonly used for testing the  
individual devices that comprise an integrated circuit  
(IC) and, in particular, the present invention relates to  
a membrane probing assembly having contacts which scrub,  
10 in a locally controlled manner, across the respective  
input/output conductors of each device so as to reliably  
wipe clear the surface oxides that are normally found on  
those conductors thereby ensuring good electrical  
connection between the probing assembly and each device.

15

BACKGROUND ART

          The trend in electronic production has been  
toward increasingly smaller geometries particularly in  
integrated circuit technology wherein a very large number  
20 of discrete circuit elements are fabricated on a single  
substrate or "wafer." After fabrication, this wafer is  
divided into a number of rectangular-shaped chips or  
"dies" where each die presents a rectangular or other  
regular arrangement of metallized contact pads through  
25 which input/output connections are made. Although each  
die is eventually packaged separately, for efficiency  
sake, testing of the circuit formed on each die is pref-  
erably performed while the dies are still joined together  
on the wafer. One typical procedure is to support the  
30 wafer on a flat stage or "chuck" and to move the wafer in  
X, Y and Z directions relative to the head of the probing  
assembly so that the contacts on the probing assembly  
move from die to die for consecutive engagement with each  
die. Respective signal, power and ground lines are run  
35 to the probing assembly from the test instrumentation  
thus enabling each circuit to be sequentially connected  
to the test instrumentation.

One conventional type of probing assembly used for testing integrated circuits provides contacts that are configured as needle-like tips. These tips are mounted about a central opening formed in a probe card so as to radially converge inwardly and downwardly through the opening. When the wafer is raised beyond that point where the pads on the wafer first come into contact with these tips, the tips flex upwardly so as to skate forwardly across their respective pads thereby removing oxide buildup on the pads.

The problem with this type of probing assembly is that the needle-like tips, due to their narrow geometry, exhibit high inductance so that electrical losses are high in measurements made through these tips. Also, these tips can act in the manner of a planing tool as they wipe across their respective pads, thereby leading to excessive pad wear. This problem is magnified to the extent that the probe tips bend out of shape during use or otherwise fail to terminate in a common plane which causes the more forward ones of the tips to bear down too heavily on their respective pads. Also, it is impractical to mount these tips at less than 100 micron center-to-center spacing or in a multi-row grid-like pattern so as to accommodate the pad arrangement of more modern, higher density dies.

In order to reduce inductive losses, decrease pad wear and accommodate smaller device geometries, a second type of probing assembly has been developed that uses a flexible membrane structure for supporting the probing contacts. In this assembly, lead lines of well-defined geometry are formed on one or more plies of flexible insulative film, such as polyimide or MYLAR™. If separate plies are used, these plies are bonded together to form, for example, a multilayered transmission line structure. In the central portion of this flexible structure or membrane, each conductive line is terminated by a respective probing contact which is formed on, and

projects outwardly from, an outer face of the membrane. These probing contacts are arranged in a predetermined pattern that matches the pattern of the device pads and typically are formed as upraised bumps for probing the flat surfaces conventionally defined by the pads. The inner face of the membrane is supported on a supporting structure. This structure can take the form, for example, of a truncated pyramid, in which case the inner face of the center portion of the membrane is supported on the truncated end of the support while the marginal portions of the membrane are drawn away from the center portion at an angle thereto so as to clear any upright components that may surround the pads on the device.

With respect to the membrane probing assembly just described, excessive line inductance is eliminated by carefully selecting the geometry of the lead lines, and a photolithographic process is preferably used to enable precise control over the size, spacing, and arrangement, of the probing contacts so as to accommodate higher density configurations. However, although several different forms of this probing assembly have been proposed, difficulties have been encountered in connection with this type of assembly in reducing pad wear and in achieving reliable clearing of the oxide layer from each of the device pads so as to ensure adequate electrical connection between the assembly and the device-under-test.

One conventional form of membrane probing assembly, for example, is exemplified by the device shown in Rath European Patent Pub. No. 259,163A2. This device has the central portion of the sheet-like membrane mounted directly against a rigid support. This rigid support, in turn, is connected by a resilient member comprising an elastomeric or rubber block to the main body of the assembly so that the membrane can tilt to match the tilt of the device. Huff U.S. Patent No. 4,918,383 shows a closely related device wherein radially

extending leaf springs permit vertical axis movement of the rigid support while preventing it from tilting so that there is no slippage or "misalignment" of the contact bumps on the pads and further so that the entire  
5 membrane will shift slightly in the horizontal plane to allow the contacts to "scrub" across their respective pads in order to clear surface oxides from these pads.

In respect to both of these devices, however, because of manufacturing tolerances, certain of the  
10 contact bumps are likely to be in a recessed position relative to their neighbors and these recessed bumps will not have a satisfactory opportunity to engage their pads since they will be drawn away from their pads by the action of their neighbors on the rigid support. Further-  
15 more, even when "scrub" movement is provided in the manner of Huff, the contacts will tend to frictionally cling to the device as they perform the scrubbing movement, that is, there will be a tendency for the pads of the device to move in unison with the contacts so as to  
20 negate the effect of the contact movement. Whether any scrubbing action actually occurs depends on how far the pads can move, which depends, in turn, on the degree of lateral play that exists as a result of normal tolerance between the respective bearing surfaces of the probe head  
25 and chuck. Hence this form of membrane probing assembly does not ensure reliable electrical connection between each contact and pad.

A second conventional form of membrane probing assembly is exemplified by the device shown in Barsotti  
30 European Patent Pub. No. 304,868A2. This device provides a flexible backing for the central or contact-carrying portion of the flexible membrane. In Barsotti, the membrane is directly backed by an elastomeric member and this member, in turn, is backed by a rigid support so  
35 that minor height variations between the contacts or pads can be accommodated. It is also possible to use positive-pressure air, negative-pressure air, liquid or an

unbacked elastomer to provide flexible backing for the membrane, as shown in Gangroth U.S. Patent No. 4,649,339, Ardezzone U.S. Patent No. 4,636,772, Reed, Jr. et al. U.S. Patent No. 3,596,228 and Okubo et al. U.S. Patent No. 5,134,365, respectively. These alternative devices, however, do not afford sufficient pressure between the probing contacts and the device pads to reliably penetrate the oxides that form on the pad surfaces.

In this second form of membrane probing assembly, as indicated in Okubo, the contacts may be limited to movement along the Z-axis in order to prevent slippage and resulting misalignment between the contacts and pads during engagement. Thus, in Barsotti, the rigid support underlying the elastomeric member is fixed in position although it is also possible to mount the support for Z-axis movement in the manner shown in Huff U.S. Patent No. 4,980,637. Pad damage is likely to occur with this type of design, however, because a certain amount of tilt is typically present between the contacts and the device, and those contacts angled closest to the device will ordinarily develop much higher contact pressures than those which are angled away. The same problem arises with the related assembly shown in European Patent Pub. No. 230,348A2 to Garretson, even though in the Garretson device the characteristic of the elastomeric member is such as to urge the contacts into lateral movement when those contacts are placed into pressing engagement with their pads. Yet another related assembly is shown in Evans U.S. Patent No. 4,975,638 which uses a pivotably mounted support for backing the elastomeric member so as to accommodate tilt between the contacts and the device. However, the Evans device is subject to the friction clinging problem already described insofar as the pads of the device are likely to cling to the contacts as the support pivots and causes the contacts to shift laterally.

Yet other forms of conventional membrane probing assemblies are shown in Crumly U.S. Patent No. 5,395,253, Barsotti et al. U.S. Patent No. 5,059,898 and Evans et al. U.S. Patent No. 4,975,638. In Crumly, the center portion of a stretchable membrane is resiliently biased to a fully stretched condition using a spring. When the contacts engage their respective pads, the stretched center portion retracts against the spring to a partially relaxed condition so as to draw the contacts in radial scrub directions toward the center of the membrane. In Barsotti, each row of contacts is supported by the end of a respective L-shaped arm so that when the contacts in a row engage their respective pads, the corresponding arm flexes upwardly and causes the row of contacts to laterally scrub simultaneously across their respective pads. In both Crumly and Barsotti, however, if any tilt is present between the contacts and the device at the time of engagement, this tilt will cause the contacts angled closet to the device to scrub further than those angled further away. Moreover, the shorter contacts will be forced to move in their scrub directions before they have had the opportunity to engage their respective pads due to the controlling scrub action of their neighboring contacts. A further disadvantage of the Crumly device, in particular, is that the contacts nearer to the center of the membrane will scrub less than those nearer to the periphery so that scrub effectiveness will vary with contact position.

In Evans et al. U.S. Patent No. 5,355,079 each contact constitutes a spring metal finger, and each finger is mounted so as to extend in a cantilevered manner away from the underlying membrane at a predetermined angle relative to the membrane. A similar configuration is shown in Higgins U.S. Patent No. 5,521,518. It is difficult, however, to originally position these fingers so that they all terminate in a common plane, particularly if a high density pattern is required.



Moreover, these fingers are easily bent out of position during use and cannot easily be rebent back to their original position. Hence, certain ones of the fingers are likely to touch down before other ones of the  
5 fingers, and scrub pressures and distances are likely to be different for different fingers. Nor, in Evans at least, is there an adequate mechanism for tolerating a minor degree of tilt between the fingers and pads. Although Evans suggests roughening the surface of each  
10 finger to improve the quality of electrical connection, this roughening can cause undue abrasion and damage to the pad surfaces. Yet a further disadvantage of the contact fingers shown in both Evans and Higgins is that such fingers are subject to fatigue and failure after a  
15 relatively low number of "touchdowns" or duty cycles due to repeated bending and stressing.

In accordance with the foregoing, an object of at least preferred embodiments of the present invention is to provide a probing assembly which can reliably make  
20 electrical connection with a high density arrangement of pads on an electrical device despite the buildup of oxides or other contaminants on the pad surfaces.

Another object of at least preferred embodiments of the present invention is to provide a  
25 membrane probing assembly that ensures adequate scrubbing action between each contact and pad despite minor variations in contact height.

Another object of at least preferred embodiments of the present invention is to provide a  
30 probing assembly that can reliably operate over a large number of duty cycles without failure.

Another object of at least preferred embodiments of the present invention is to provide a  
35 membrane probing assembly providing uniformly effective scrubbing action in respect to the contacts independent of the respective positions of the contacts.

## DISCLOSURE OF THE INVENTION

A probing assembly system for probing an electrical device in accordance with the present invention provides a forward support of incompressible material, a flexible membrane assembly mounted with its central region overlying the support, a plurality of rigid contacts disposed on the membrane assembly within the central region each including a beam and a contacting portion, each contacting portion being arranged in suitable position for pressing engagement with a corresponding pad on the device, each beam being electrically connected to a corresponding flexible conductor that extends into the central region. In accordance with the present invention, the probing assembly further provides a pressure control mechanism including an elastomeric member interposed between each contact and the support and a motion control mechanism locally operating in respect to each contact to urge each beam, when the corresponding contacting portion is placed into pressing engagement with the respective pad, into tilting motion so that different portions of each beam move different distances relative to the forward support and so that each contact is driven, in accordance with this tilting motion, into a lateral scrubbing movement across the corresponding pad. The elastomeric member is positioned so as to resiliently oppose the tilting motion and so as to enable each contact to recover from this tilting motion in a manner avoiding mechanical straining of each beam.

In accordance with the foregoing system, a high-density arrangement of contacts can be provided on the probing assembly using, for example, a photolithographic process to define both the contacts and their lead-in conductors on the flexible membrane assembly. The resiliency of the elastomeric member accommodates minor height variations that may exist between adjacent ones of the contacts, and the incompressible support that

backs the elastomeric member ensures that this member will sufficiently bear against the contacts to maintain an adequate level of contact-to-pad pressure during scrubbing. The elastomeric member further serves as a reliable mechanism for enabling the beam of each rigid contact to recover after tilting thereby avoiding the need to rely on the type of elastic recovery provided by mechanically strained contact needles or fingers, which alternative system can lead to ineffective electrical performance as the contact needles or fingers bend out of shape during use or prematurely fail due to bending fatigue. Further in accordance with the present invention, by urging each contact into tilting motion by means of a locally operating motion control mechanism so that different portions of each beam move different distances relative to the support and so that each contact is thereby driven into lateral wiping movement across the corresponding pad, scrubbing action between the contacts and pads is achieved in a manner effective for clearing oxides from the pads. It is possible, in particular, to achieve a high level of scrub effectiveness in relation to each contact on the assembly in accordance with this type of localized tilt control.

The foregoing and other objectives, features, and advantages of the invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing an exemplary membrane probing assembly bolted to a probe head and a wafer supported on a chuck in suitable position for probing by this assembly.

FIG. 2 is a bottom elevational view showing various parts of the probing assembly of FIG. 1, including a support element and flexible membrane assembly, and

a fragmentary view of a probe card having data/signal lines connected with corresponding lines on the membrane assembly.

FIG. 3 is a side elevational view of the membrane probing assembly of FIG. 1 where a portion of the membrane assembly has been cut away to expose hidden portions of the support element.

FIG. 4 is a top elevational view of an exemplary support element.

FIGS. 5a-5b are schematic side elevational views illustrating how the exemplary support element and membrane assembly are capable of tilting to match the orientation of the device under test.

FIG. 6 is an enlarged top elevational view of the central region of an exemplary construction of the membrane assembly of FIG. 2.

FIGS. 7a-7b are sectional views taken along lines 7a-7a in FIG. 6 first showing an exemplary contact before touchdown and then showing the same contact after touchdown and scrub movement across its respective pad.

FIG. 8 is a schematic side view showing, in dashed-line representation, the exemplary contact of FIGS. 7a-7b at the moment of initial touchdown and, in solid-line representation, the same contact after further vertical overtravel by the pad.

FIGS. 9a-9b are schematic side views showing three of the exemplary contacts of FIG. 6 and how such contacts engage their respective pads despite minor height variations between the contacts.

FIGS. 10a-10b are top views comparable to FIG. 6 but showing alternative contact patterns. FIG. 10c is a side elevational view showing the appearance of the contacts in each of these patterns after touchdown and scrub across their respective contacts.

FIGS. 11a-11f are sectional side views of an alternative embodiment of the center portion of the

membrane probing assembly in successive stages of manufacture. FIG. 11f shows the final construction.

FIG. 12 is a schematic side view showing, in dashed-line representation, a contact of the alternative embodiment of FIG. 11f at the moment of initial touchdown and, in solid-line representation, the same contact after further vertical overtravel by the pad.

FIG. 13 is a top elevational view of the alternative embodiment shown in FIG. 11f.

FIG. 14 is a top elevational view of a modified form of the alternative embodiment shown in FIG. 11f.

#### BEST MODES FOR CARRYING OUT THE INVENTION

FIG. 1 shows a probe head 40 for mounting a membrane probing assembly 42 constructed in accordance with the present invention. In order to measure the electrical performance of a particular die area 44 included on the silicon wafer 46, the high-speed digital lines 48 and/or shielded transmission lines 50 of the probe head are connected to the input/output ports of the test instrumentation by a suitable cable assembly, and the chuck 51 which supports the wafer is moved in mutually perpendicular X,Y,Z directions in order to bring the pads of the die area into pressing engagement with the contacts included on the lower contacting portion of the membrane probing assembly.

The probe head 40 includes a probe card 52 on which the data/signal lines 48 and 50 are arranged. Referring to FIGS. 2-3, the membrane probing assembly 42 includes a support element 54 formed of incompressible material such as a hard polymer. This element is detachably connected to the upper side of the probe card by means of four Allen screws 56 and corresponding nuts 58 (each screw passes through a respective attachment arm 60 of the support element, and a separate backing element 62 evenly distributes the clamping pressure of the screws over the entire back side of the supporting element). In

accordance with this detachable connection, different probing assemblies having different contact arrangements can be quickly substituted for each other as needed for probing different devices.

5                   Referring to FIGS. 3-4, the support element 54 includes a rearward base portion 64 to which the attachment arms 60 are integrally joined. Also included on the support element 54 is a forward support or plunger 66 that projects outwardly from the flat base portion. This  
10 forward support has angled sides 68 that converge toward a flat support surface 70 so as to give the forward support the shape of a truncated pyramid. Referring also to FIG. 2, a flexible membrane assembly 72 is attached to the support after being aligned by means of alignment  
15 pins 74 included on the base portion. This flexible membrane assembly is formed by one or more plies of insulative sheeting such as KAPTON™ sold by E.I. Du Pont de Nemours or other polyimide film, and flexible conductive layers or strips are provided between or on these plies  
20 to form the data/signal lines 76.

When the support element 54 is mounted on the upper side of the probe card 52 as shown in FIG. 3, the forward support 66 protrudes through a central opening 78 in the probe card so as to present the contacts which are  
25 arranged on a central region 80 of the flexible membrane assembly in suitable position for pressing engagement with the pads of the device under test. Referring to FIG. 2, the membrane assembly includes radially extending arm segments 82 that are separated by inwardly curving  
30 edges 84 that give the assembly the shape of a formee cross, and these segments extend in an inclined manner along the angled sides 68 thereby clearing any upright components surrounding the pads. A series of contact pads 86 terminate the data/signal lines 76 so that when  
35 the support element is mounted, these pads electrically engage corresponding termination pads provided on the upper side of the probe card so that the data/signal

lines 48 and 50 on the probe card are electrically connected to the contacts on the central region.

An important feature of the exemplary membrane probing assembly 42 is its capability for probing a high-density arrangement of contact pads over a large number of contact cycles in a manner that ensures reliable electrical connection between the contacts and pads in each cycle despite oxide buildup on the pads. This capability is a function of the construction of the support element 54, the flexible membrane assembly 72 and their manner of interconnection. In particular, the membrane assembly is so constructed and connected to the support element that the contacts on the membrane assembly preferably wipe or scrub, in a locally controlled manner, laterally across the pads when brought into pressing engagement with these pads. The preferred mechanism for producing this scrubbing action will now be described in connection with the construction and interconnection of a preferred membrane assembly 72a as best depicted in FIGS. 6 and 7a-7b.

FIG. 6 shows an enlarged view of the central region 80a of the preferred membrane assembly 72a. In this embodiment, the contacts 88 are arranged in a square-like pattern suitable for engagement with a square-like arrangement of pads. Referring also to FIG. 7a, which represents a sectional view taken along lines 7a-7a in FIG. 6, each contact comprises a relatively thick rigid beam 90, preferably 150 to 250 microns long, at one end of which is formed a rigid contact bump 92. The contact bump includes thereon a contacting portion 93, which, in the embodiment illustrated, comprises a nub of rhodium nickel alloy fused to the contact bump, although the contacting portion may, alternatively, comprise the rounded sides of the contact bump itself. Using a conventional process, such as electroplating, each beam is preferably formed in an overlapping connection with the end of a flexible conductive trace

76a to form a large surface joint therewith. This conductive trace in conjunction with a backplane conductive layer 94 effectively provides a controlled impedance data/signal line to the contact and hence its dimensions are preferably established precisely using a photolithographic process. The backplane layer preferably includes openings therein to assist, for example, with gas venting during fabrication.

For ease of illustration, the flexible membrane assembly 72a is shown as having only a single dielectric ply 96, preferably polyimide; however, multiple dielectric plies and conductive layers will normally be used in accordance with conventional layering techniques. The membrane assembly is interconnected to the flat support surface 70 by an interposed elastomeric layer 98, which layer is coextensive with the support surface and can be formed by a silicon rubber compound such as ELMER'S STICK-ALL™ made by the Borden Company or Sylgard 182 by Dow Corning Corporation. This compound can be conveniently applied in a paste-like phase which hardens as it sets. The flat support surface, as previously mentioned, is made of incompressible material and is preferably a hard dielectric such as polysulfone or glass.

In accordance with the above-described construction, when one of the contacts 88 is brought into pressing engagement with a respective pad 100, as indicated in FIG. 7b, the resulting off-center force on the rigid beam 90 and bump 92 structure causes the beam to pivot or tilt against the elastic recovery force provided by the elastomeric pad 98. This tilting motion is localized in the sense that a forward portion 102 of the beam moves a greater distance toward the flat support surface 70 than a rearward portion 104 of the same beam. The effect is such as to drive the contact into lateral scrubbing movement across the pad as is indicated in FIG. 7b with a dashed-line and solid-line representation showing the beginning and ending positions, respectively,



of the contact on the pad. In this fashion, the insulative oxide buildup on each pad is removed so as to ensure reliable contact-to-pad electrical connections.

FIG. 8 shows, in dashed line view, the relative positions of the contact 88 and pad 100 at the moment of initial engagement or touchdown and, in solid-line view, these same elements after "overtravel" of the pad by a distance 106 in a vertical direction directly toward the flat support surface 70. As indicated, the distance 106 of lateral scrubbing movement is directly dependent on the vertical deflection of the contact 88 or, equivalently, on the overtravel distance 108 moved by the pad 100. Hence, since the overtravel distance for each contact on the central region 80a will be substantially the same (with differences only arising from minor variations in contact height), the distance of lateral scrubbing movement by each contact on the central region will be substantially uniform and will not, in particular, be affected by the relative position of each contact on the central region.

Because the elastomeric layer 98 is backed by the incompressible support surface 70, the elastomeric layer exerts a sufficient recovery force on each tilting beam 90 and thus each contact 88 to maintain an adequate level of contact-to-pad pressure during scrubbing. At the same time, the elastomeric layer accommodates minor height variations between the respective contacts. Thus, referring to FIG 9a, when a relatively shorter contact 88a is situated between an immediately adjacent pair of relatively taller contacts 88b and these taller contacts are brought into engagement with their respective pads, then, as indicated in FIG. 9b, deformation by the elastomeric layer allows the smaller contact to be brought into engagement with its pad after only a small amount of further overtravel by the pads. It will be noted, in this example, that the tilting action of each contact is locally controlled, and the larger contacts are able, in

particular, to tilt independently of the smaller contact so that the smaller contact is not urged into lateral movement until it has actually touched down on its pad.

In respect to the preferred membrane assembly 72a, not only is the distance and pressure of the scrub action of each contact 88 well regulated, but so also is the scrub direction. In FIG. 6 the respective scrub directions of contacts 88c-f are indicated by means of directional arrows 112c-f. As shown, each contact scrubs forwardly in the direction of the longitudinal axis of its beam 90. Preferably, as further shown, the contacts are arranged in pairs (88c, 88d or 88e, 88f) in which the respective contacts of each pair scrub in opposite directions. Accordingly, in relation to the wafer or device on which the pads are formed, the scrubbing force exerted on the device by the first contact of each pair is cancelled out by the scrubbing force exerted by the second contact of each pair. Hence, the device is not dragged frictionally along by these scrubbing forces in a manner that can reduce or even prevent desirable scrubbing action between the contacts and pads.

In addition to providing reliable electrical connection with the device under test, the preferred membrane assembly 72a is able to provide such connection over a large number of contact or touchdown cycles. The elastomeric layer 98, in particular, serves as a reliable mechanism for enabling each beam 90 to recover from each touchdown operation, thereby avoiding the need to rely on a failure prone recovery mechanism such as bending and mechanical straining of any portion of the stiff contacts themselves. To prevent excessive wearing of the contacts 88, as mentioned above, each contact includes a contacting portion or nub 93 of rhodium nickel alloy, and the beam 90 and contact bump 92 are also formed of nickel alloy. The flexible traces 76a are preferably of highly conductive metal, such as gold, for good connection with the contacts.

Referring to FIG. 4, L-shaped slots 114 are formed in the rearward base portion 64 to permit the forward support 66 to tilt relative to the base portion. Accordingly, if the flat support surface 70 and the device under test 116 are in tilted relationship to each other prior to touchdown, as shown in FIG. 5a, when touchdown occurs, the engagement pressure between the contacts 88 and pads 100 will automatically move the support surface to a position parallel with the device, as shown in FIG. 5b. This prevents those ones of the contacts that are initially angled closest to the device from bearing down too heavily on their pads which can result in damage to the pad surfaces. Also, this normalizes the distance between the support surface and each pad once full engagement is reached. Since this pad-to-surface distance determines the amount of deflection of each contact and since this deflection determines the scrub pressure and distance for each contact as hereinabove described, the respective scrub pressures and distances of the contacts are therefor normalized in respect to each other despite any ordinary amount of initial tilt that may exist between the support surface and device.

In addition to providing reliable electrical connections over a large number of contact cycles, the exemplary membrane probing assembly 42 can also be configured to accommodate the high density arrangement of contact pads of the type found on more modern devices. Referring, for example, to FIG. 10a, the contacts 88 can be arranged so as to be aligned with each other in rows and columns. The contact bumps 92 thus conform to a 2-dimensional grid pattern corresponding to the pad pattern of higher density devices. A 2-dimensional grid pattern can also be achieved by arranging the contacts in chevron-shaped pairs as shown in FIG 10b. In this arrangement, the length of each beam 90 is preferably longer than or nearly as long as half the spacing between

the contact bumps so that only a one-dimensional deformation of the polyimide ply layers 116 is required as schematically represented in FIG. 10c (the deformation of the polyimide ply layers for the row and column arrangement of contacts would look the same from the view shown). In these higher density embodiments, the conductive traces that form the data/signal lines to the contacts pass between the polyimide layers, and each trace is connected to the corresponding contact by a conductive through via (not shown).

An exemplary flexible membrane assembly 72a and its interconnection to the flat support surface 70 by an elastomeric layer 98 has now been described. This construction provides an exemplary embodiment for the contacting portion of the membrane probing assembly 42. However, it will be recognized that alternative embodiments of the contacting portion are also possible without departing from the broader principles of the present invention.

FIGS. 11a-11e show a sequence of steps used in the construction of an alternative embodiment 174 of the center portion of the membrane assembly. The finished construction is shown in FIGS. 11f and 13.

Referring to FIG. 11f, in this alternative embodiment, rigid contact beams 176, such as of rhodium nickel alloy, are provided on the outer face of the flexible membrane assembly 178. To accommodate a high density contact pattern (FIG. 13), the membrane assembly is formed by multiple polyimide layers 180 (only two layers are shown for ease of illustration) and includes a conductive backplane 182 and flexible striplike lines 184 that pass through the layers. Each line connects to a respective contact beam by a through via 186 and a short conductive trace 188 (preferably of highly conductive metal such as gold for good electrical contact with the nickel alloy beam) to provide the required data/signal line.

A bonding compound 190 attaches the membrane assembly to the flat support surface 70 except for U-shaped flap portions 192 of the assembly. These flap portions each support a respective one of the contact beams and are formed by U-shaped slits 194 (FIG. 13) cut through the assembly. An elastomeric hub 196 is attached beneath each flap portion. This hub maintains the corresponding contact beam in an inclined position relative to the support surface and enables the beam to tilt in a localized manner in relation to the surface.

Referring to FIG. 12, when each contact beam 176 touches down on its respective pad 100, the U-shaped flap portion 192 is deflected toward the flat support surface 70 against the resilient bias provided by the elastomeric hub 196. This causes the contact beam to tilt relative to the support surface in such a manner that different portions (forward and rearward) of this beam-shaped contact move different distances relative to the surface and the contact beam is driven into lateral scrubbing movement across the pad. The distance 198 of this lateral scrubbing movement directly depends on the distance of vertical deflection of the contact beam or, equivalently, on the distance of overtravel 200 of the pad beyond the position of initial touchdown. Aside from minor variations in contact height, this distance will be substantially the same for each beam-shaped contact thereby resulting in uniform scrub movements by the different contacts.

Although they are not as convenient to manufacture as the unitary elastomeric layer 98 (refer to FIG. 8), the elastomeric hubs 196 collectively provide the same primary functions as this layer. That is, each elastomeric hub, acting in conjunction with the incompressible support surface 70, ensures that the corresponding contact beam 176 will bear down with sufficient pressure as it scrubs across its pad and, once engagement is complete, ensures that the contact beam will recover

from its tilting motion in a manner that avoids bending or mechanical straining of the beam. This approach is preferable over that of providing a contact beam or finger where a portion of the beam is bent in a cantilevered manner away from the underlying support. Under this latter approach, the inherent resiliency of the metal contained in the beam is relied on to provide the recovery mechanism, and the beam is therefor subject to strain fatigue and premature failure.

Referring to FIGS. 11a and 11b, in constructing the alternative contacting portion 174, first a sacrificial substrate 204 is provided and openings 206 are formed in the substrate, nominally of 3 mil depth, in the desired locations for the elastomeric hubs 196. The openings are then filled with silicon rubber to form the hubs 196, as shown in FIG. 11c, and the preassembled flexible membrane assembly 178 is bonded to the substrate and hubs, as shown in FIG. 11d. Next the sacrificial substrate is dissolved or etched away leaving the hubs attached to the membrane assembly, and the U-shaped slits 194 are cut through the assembly as shown in FIG. 11e. Finally, the bonding compound 190 is applied to the backside of the membrane assembly so as to run about halfway into each U-shaped slit, and the entire assembly is pressed down against the support surface 70 in such a manner that each beam-shaped contact 176 is turned outwardly by means of rolling action about the corresponding hub to an inclined position as shown in FIG. 11f. The finished construction is shown in side sectional view in FIG. 11f and in top view in FIG. 13.

In the contact pattern shown in FIG. 13, the contact beams 176 are arranged in parallel rows of opposite direction on the central region 208 of the flexible membrane assembly. Alternative contact patterns are also possible as shown in FIG. 14 where, on the central region 210, the contact beams 212 are arranged in clusters of four where each contact in a particular cluster extends

in one of the four compass directions (north, south, east, or west). It will be noted that in neither pattern do all the contacts scrub in the same direction in a manner likely to cause the pads of the device to be  
5 dragged frictionally along by the contacts. Hence the contact patterns shown help to ensure that effective scrubbing action occurs between the contact beams and pads.

An exemplary construction for a membrane  
10 probing assembly 42 as well as an alternative construction for the center portion of the assembly and a variation thereof have now been shown and described. However, it will be recognized that other constructions are possible without departing from the broader principles of the  
15 present invention.

The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expres-  
20 sions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

## WE CLAIM:

1. A probing assembly for probing an electrical device comprising:

- 5           (a) a forward support of incompressible material;
- (b) a flexible membrane assembly having a central region positioned in overlying relationship to said forward support;
- 10          (c) a plurality of rigid contacts disposed on said central region each including a beam and a contacting portion, each contacting portion being arranged in suitable position for pressing engagement with a corresponding pad on said device, each beam
- 15           being electrically connected to a corresponding flexible conductor that extends into said central region;
- (d) a pressure control mechanism including an elastomeric member interposed between each
- 20           contact and said support; and
- (e) a motion control mechanism locally operating in respect to each contact to urge each beam, when the corresponding
- 25           contacting portion is placed into pressing engagement with the respective pad, into tilting motion so that different portions of each beam move different distances relative to said forward support and so
- 30           that each contact is driven in accordance with said tilting motion into lateral scrubbing movement across the corresponding pad, said elastomeric member being positioned so as to enable each beam to
- 35           recover from said tilting motion in a manner avoiding mechanical straining of each beam.



2. The probing assembly of claim 1 wherein each one of said beams is tiltable independently of the other ones of said beams.

5           3. The probing assembly of claim 1 including a rearward base, said forward support being tiltably coupled to said rearward base so as to enable said forward support to automatically tilt relative to said rearward base toward a position parallel to said device  
10 in response to pressing engagement between respective ones of said contacting portions and corresponding ones of said pads.

          4. The probing assembly of claim 1 wherein  
15 said contacting portion of each contact is included on a contact bump fixedly joined in off-centered location on the corresponding beam.

          5. The probing assembly of claim 1 wherein  
20 said contacts are provided in pairs and the respective lateral scrubbing movements of said contacts in each pair are in opposite directions.

          6. The probing assembly of claim 1 wherein  
25 the distance of said lateral scrubbing movement of each contact after touchdown of each contacting portion on the corresponding pad is uniformly dependent for each contact on the distance traveled after touchdown in reducing the spacing between said support and said corresponding pad.  
30

          7. The probing assembly of claim 1 wherein said elastomeric member is a unitary structure.

          8. The probing assembly of claim 1 wherein  
35 said contacts are arranged by rows and columns.

9. The probing assembly of claim 1 wherein each beam is joined in overlapping relationship to the corresponding flexible conductor.

5           10. The probing assembly of claim 1 wherein said flexible membrane assembly is substantially continuous along said central region.

10           11. The probing assembly of claim 1 wherein each contact is supported by a continuous portion of said flexible membrane assembly.

15           12. A method for probing an electrical device comprising:

- (a) providing a forward support of incompressible material;
- (b) providing a flexible membrane assembly having a central region positioned in  
20           overlying relationship to said forward support;
- (c) providing a plurality of rigid contacts disposed on said central region each including a beam and a contacting portion,  
25           each contacting portion being arranged in suitable position for pressing engagement with a corresponding pad on said device, each beam being electrically connected to a corresponding flexible conductor that  
30           extends into said central region;
- (d) providing a pressure control mechanism including an elastomeric member interposed between each contact and said support; and
- (e) urging each beam, when the corresponding  
35           contacting portion is placed into pressing engagement with the respective pad, into tilting motion so as to move different

portions of each beam different distances  
relative to said support and so as to  
drive each contact in accordance with said  
tilting motion into lateral scrubbing  
5 movement across the corresponding pad,  
further including resiliently opposing  
said tilting motion by means of said  
elastomeric member so as to enable each  
contact to recover from said tilting  
10 motion in a manner avoiding mechanical  
straining of each beam.

13. The method of claim 12 including urging a  
shorter one of said contacts into tilting motion at a  
15 later time than an immediately neighboring larger one of  
said contacts.

14. The method of claim 12 including providing  
a rearward support tiltably coupled to said forward  
20 support and automatically tilting said forward support  
relative to said rearward support toward a position para-  
lled to said device in response to pressing engagement  
between respective ones of said contacting portions and  
corresponding ones of said pads.

25 15. The method of claim 12 including providing  
contacts in pairs and driving said contacts in each pair  
so that the respective lateral scrubbing movements are in  
opposite directions.

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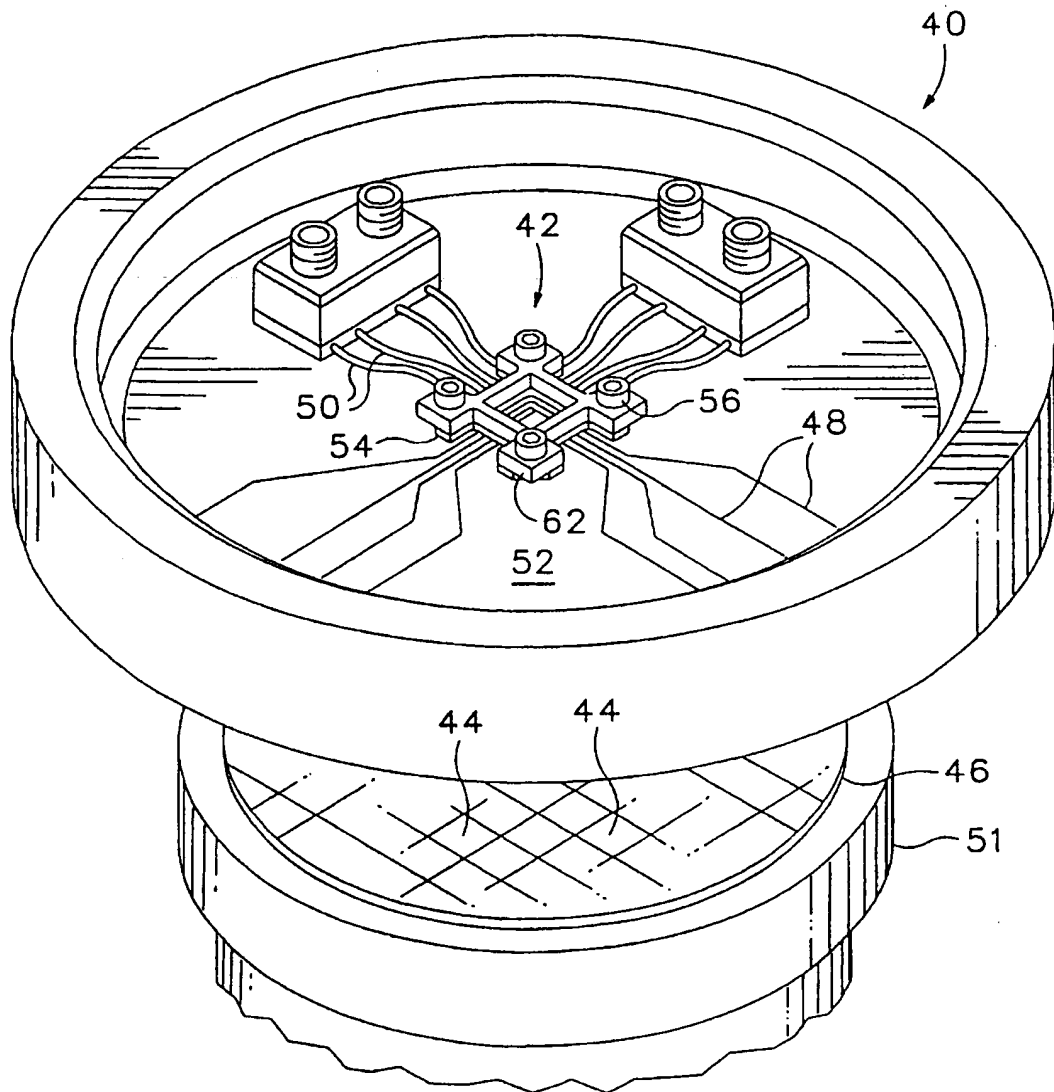
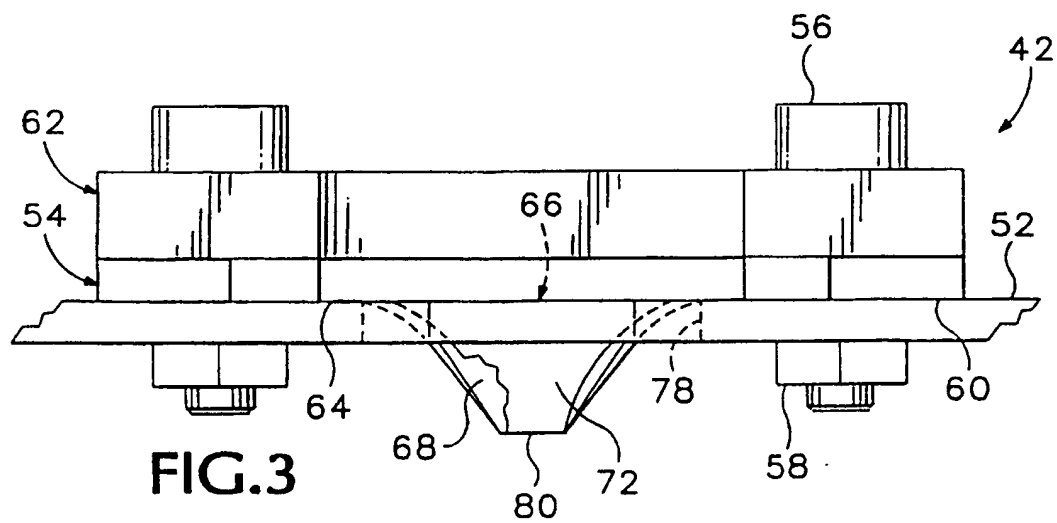
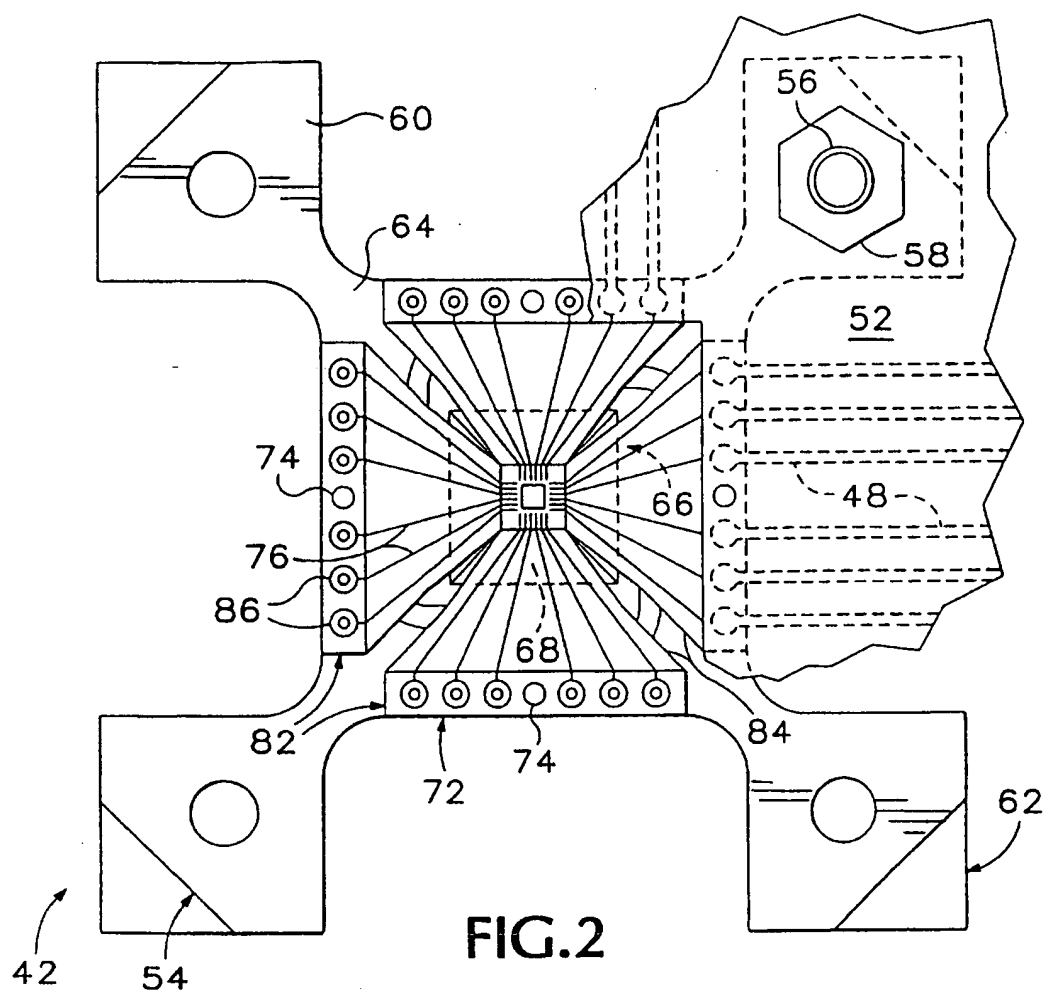
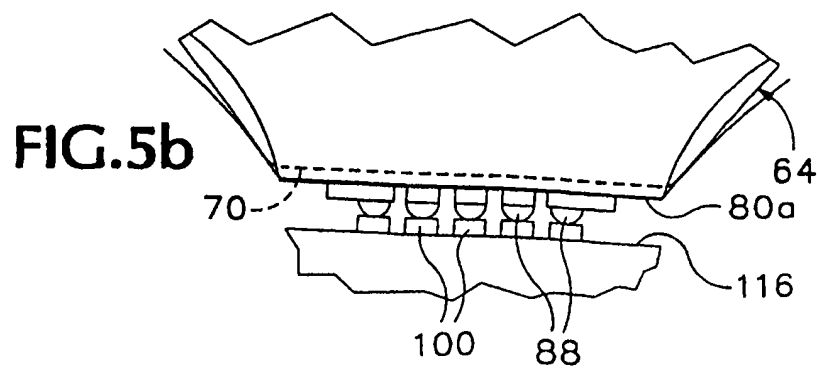
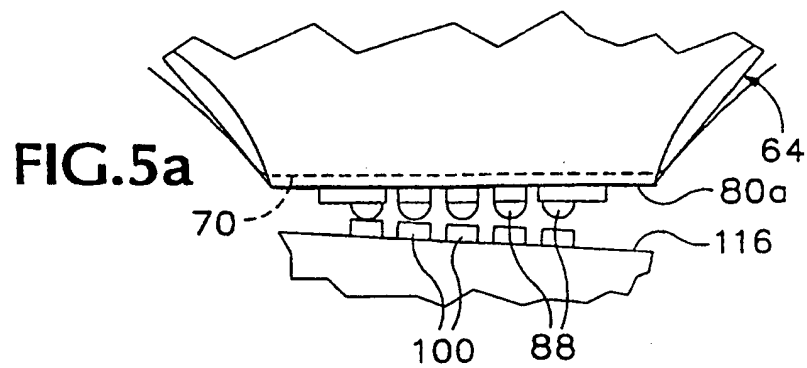
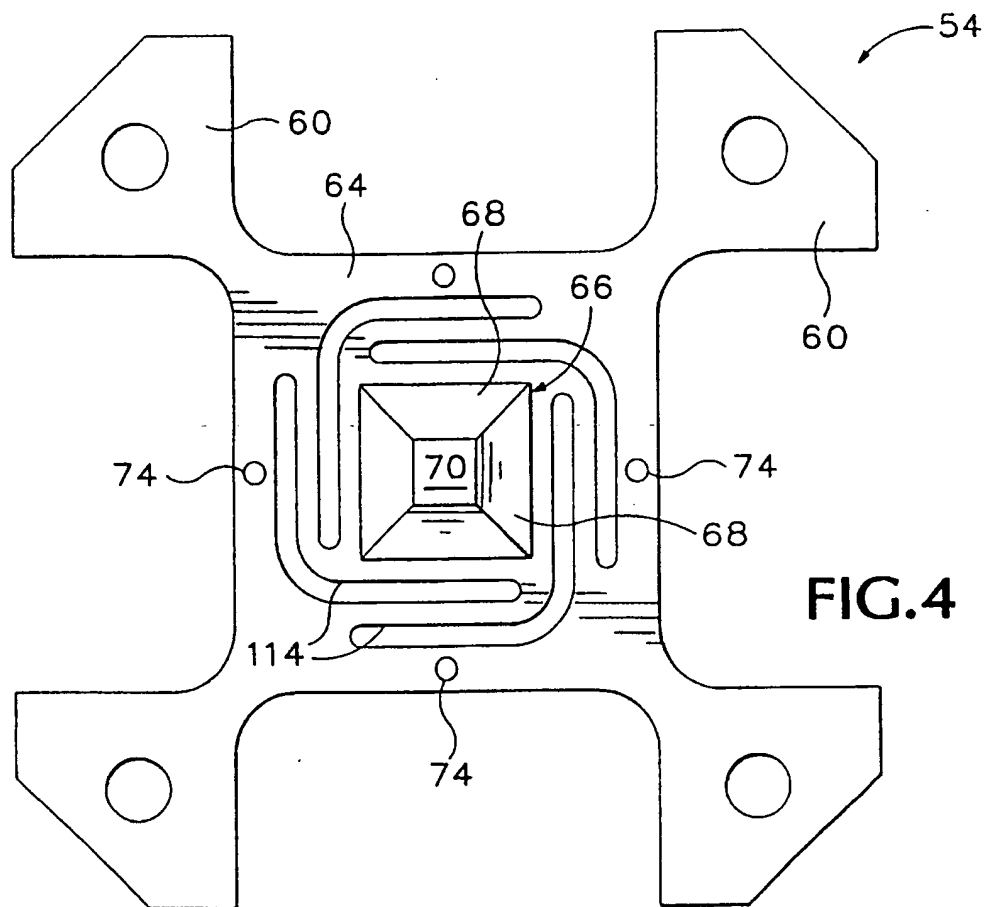
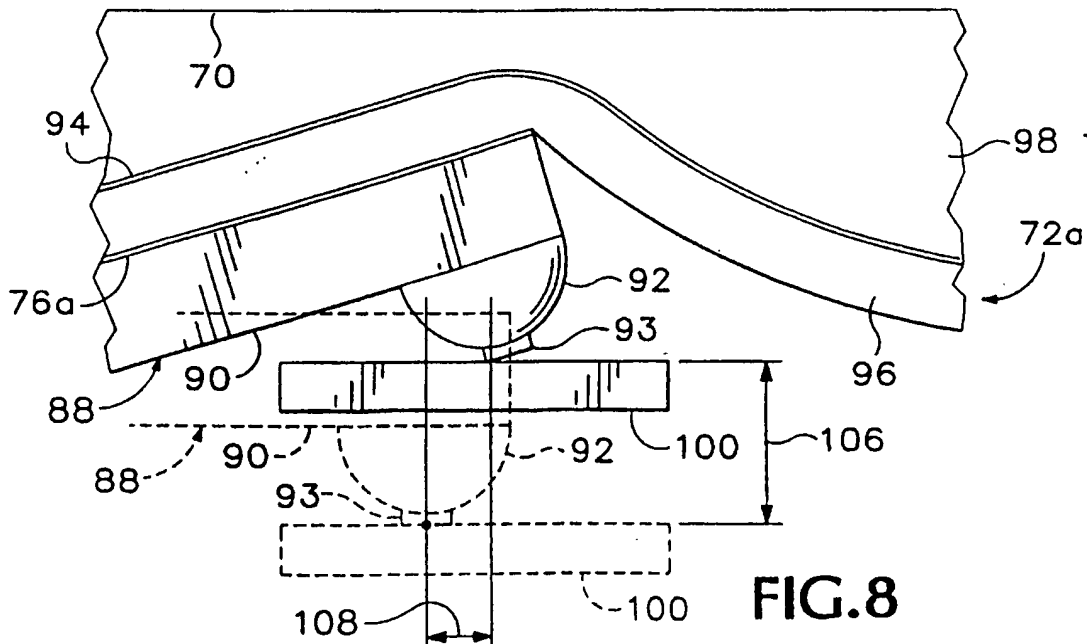
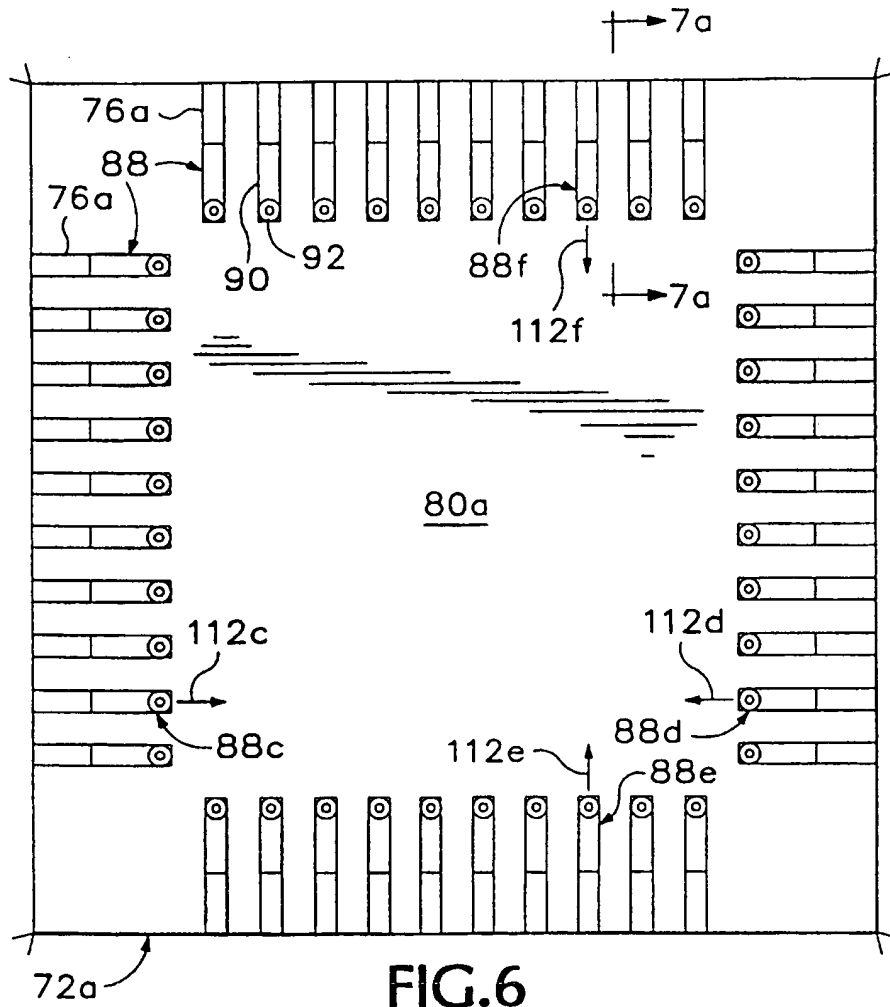
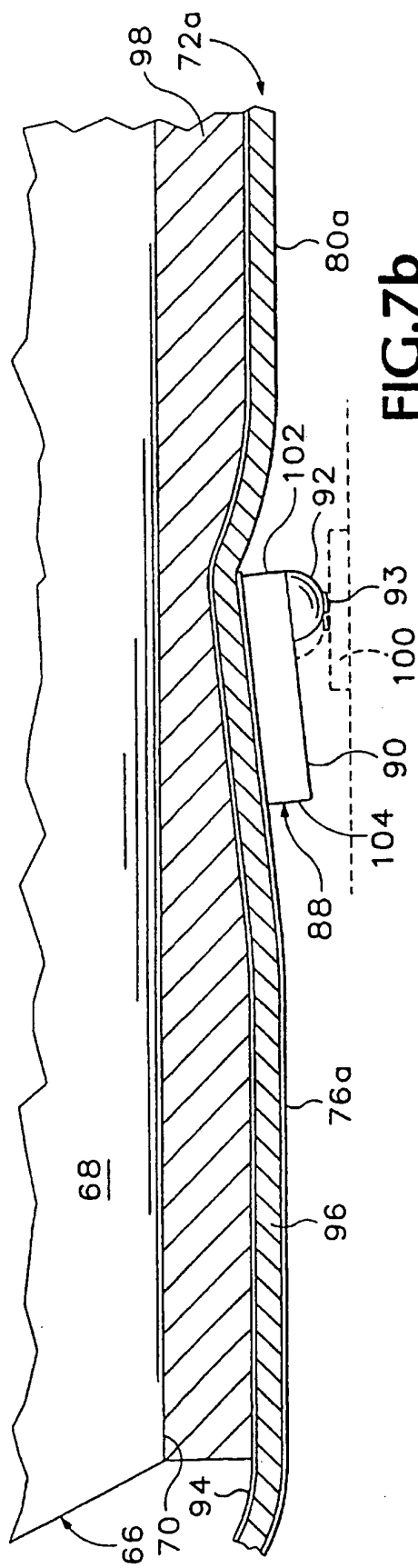
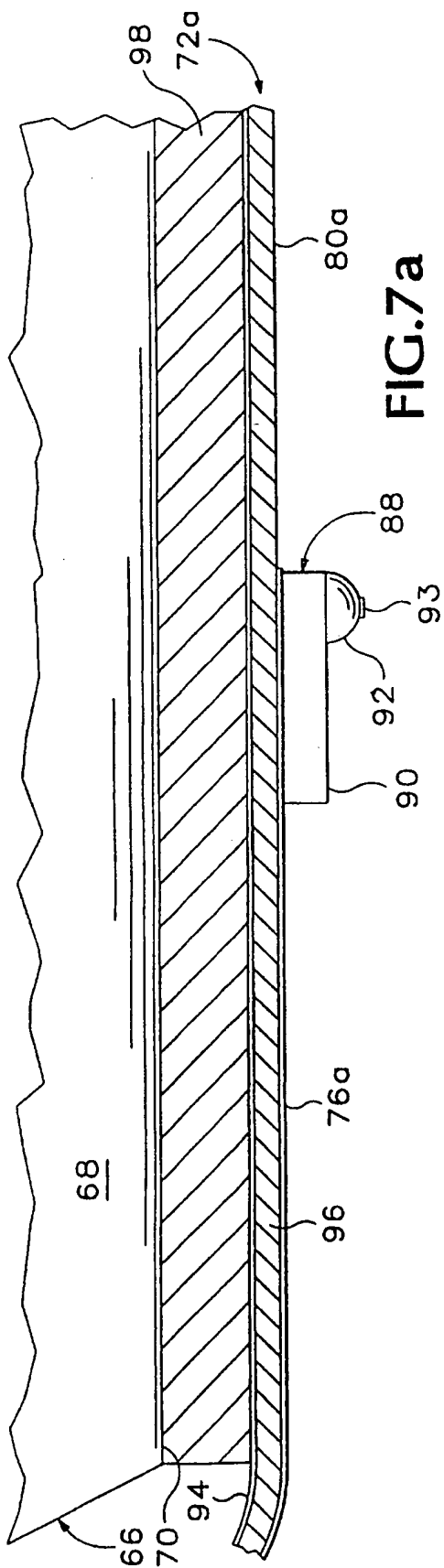


FIG.1











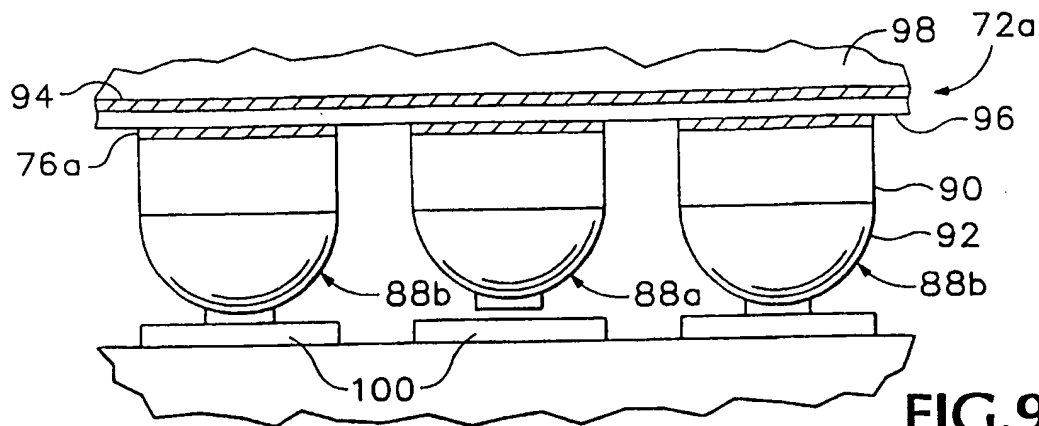


FIG. 9a

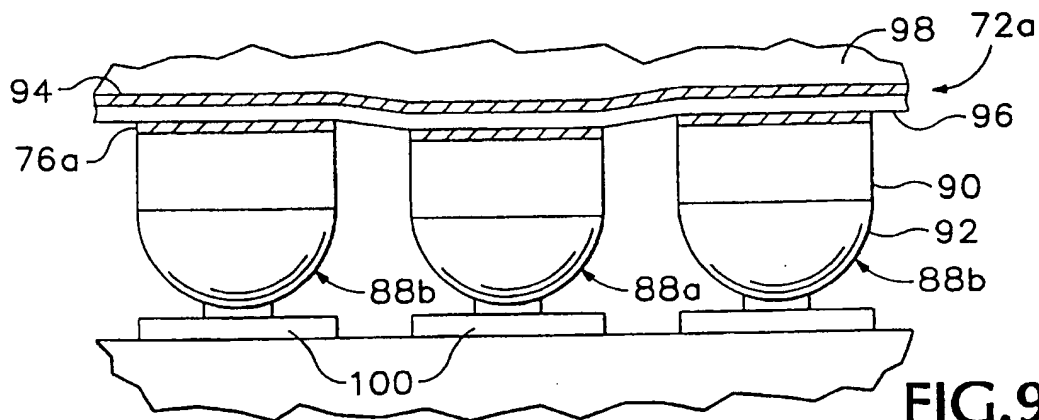


FIG. 9b

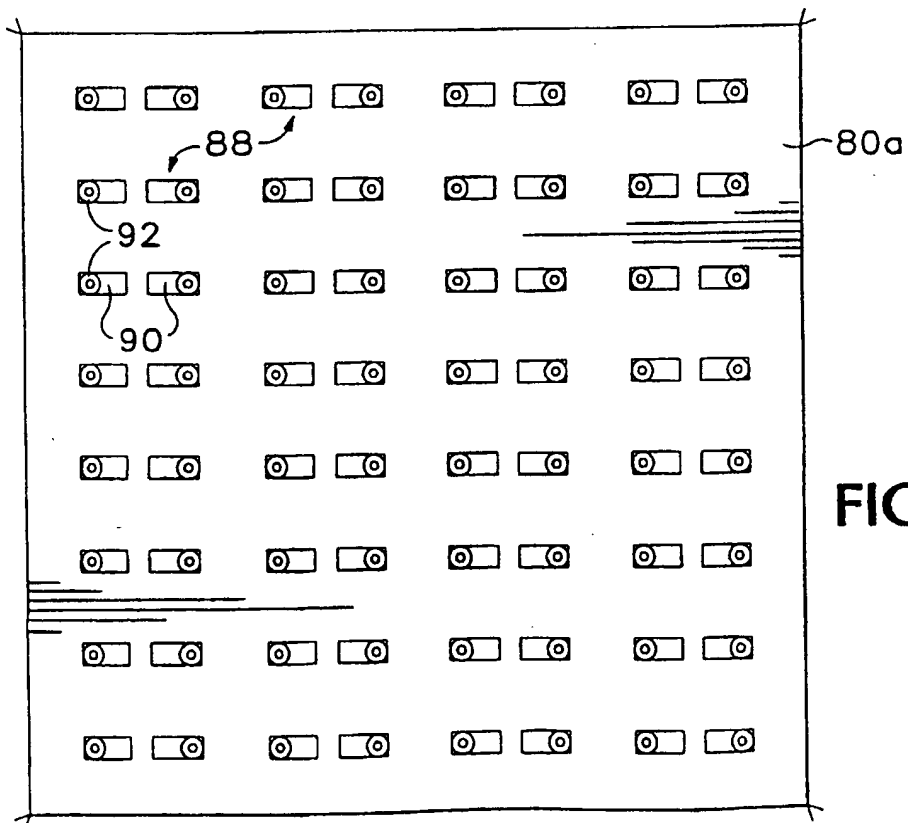


FIG. 10a

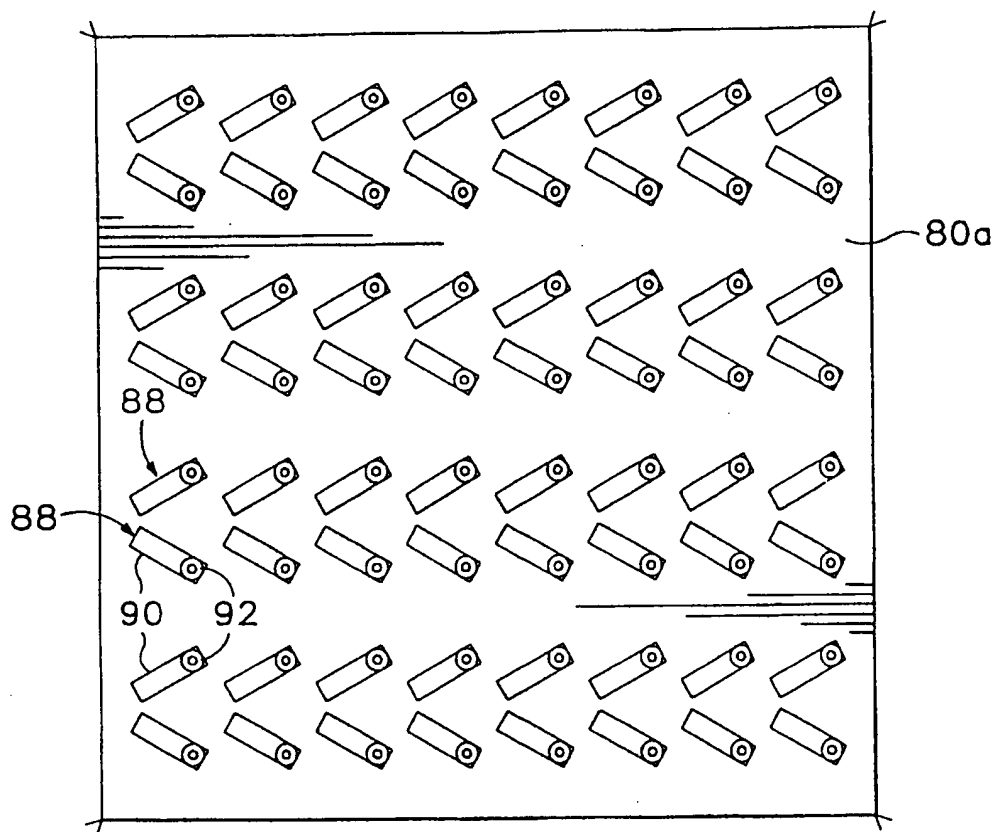


FIG. 10b

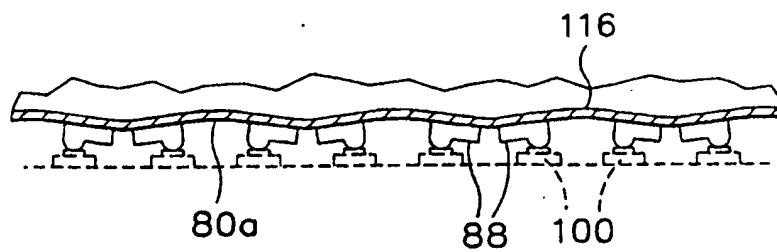


FIG. 10c

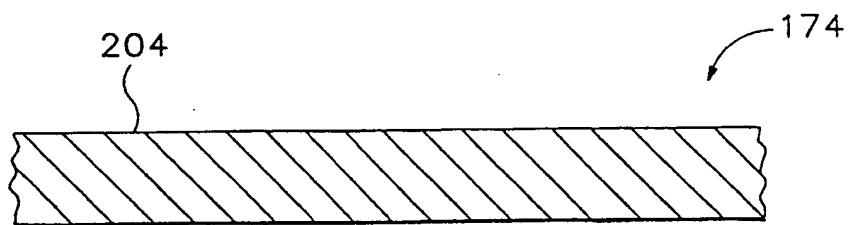


FIG. 11a

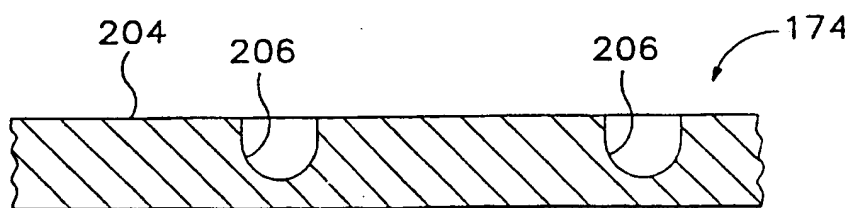


FIG. 11b

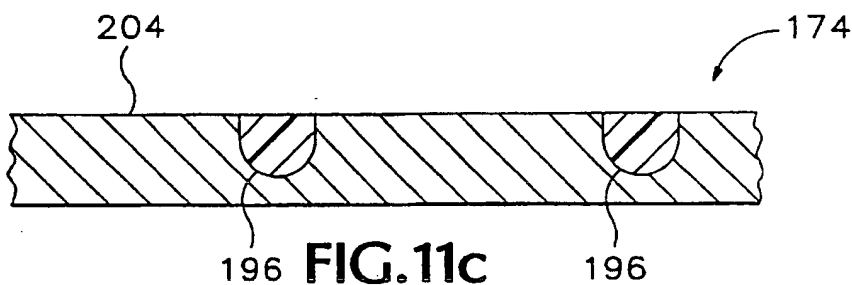


FIG. 11c

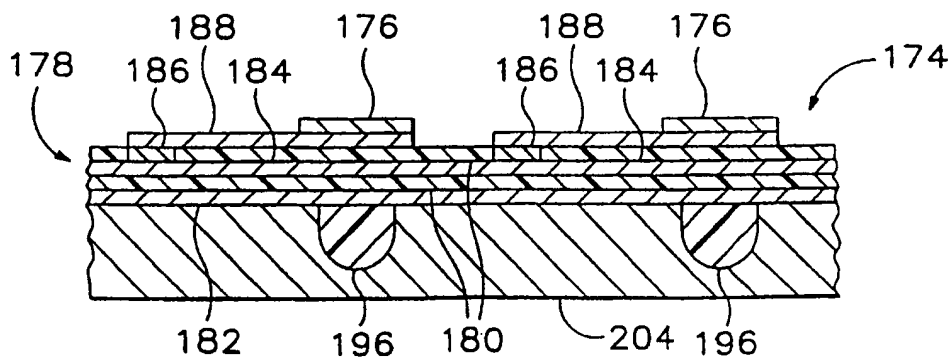
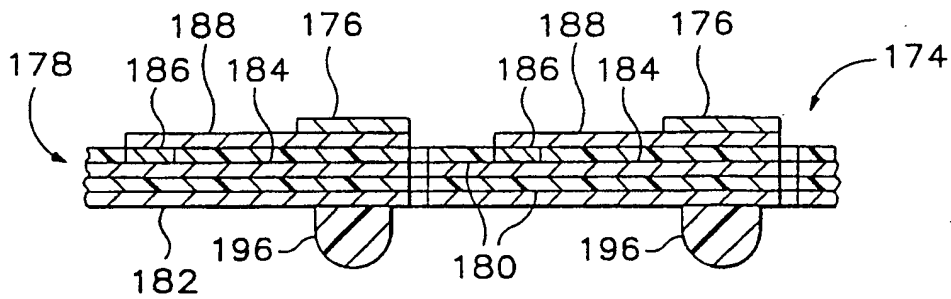
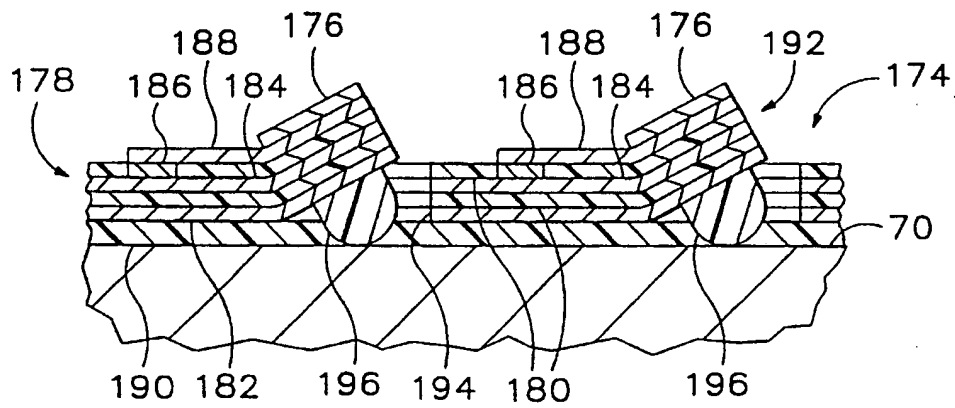


FIG. 11d



**FIG.11e**



**FIG.11f**

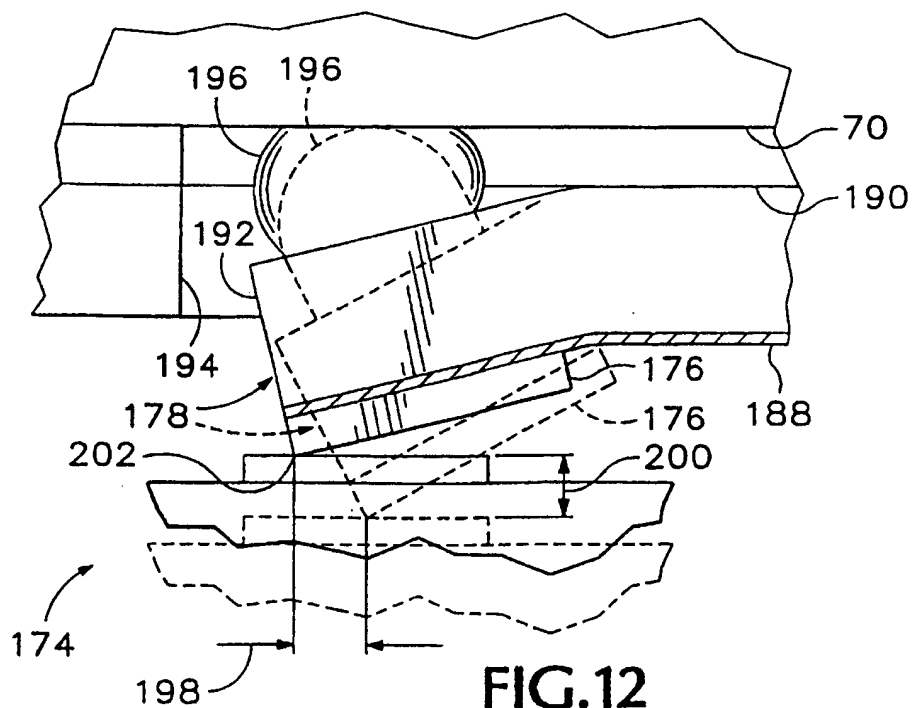


FIG.12

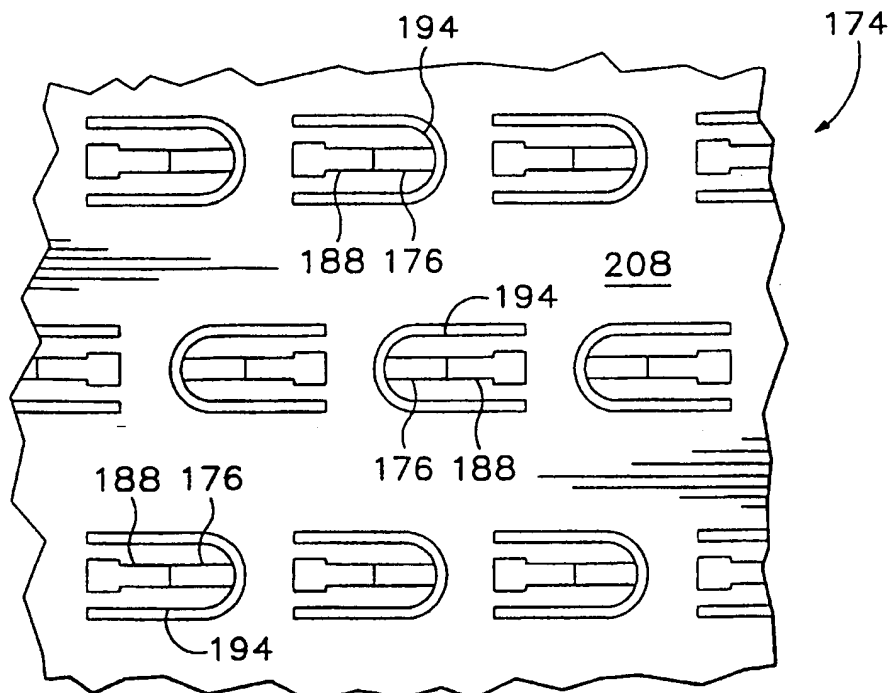


FIG. 13

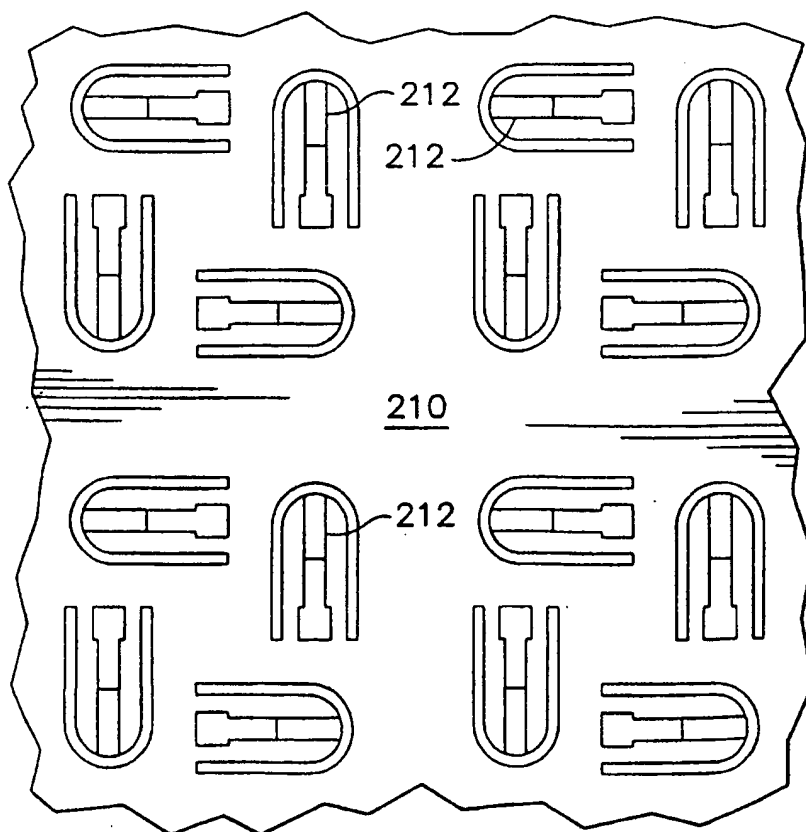


FIG. 14

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/08292

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : G01R 31/02

US CL : 324/754, 755

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 324/754, 755, 72.5; 439/482

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,980,637 A (HUFF ET AL) 25 DECEMBER 1990, SEE ENTIRE DOCUMENT.	1-15
A	US 4,649,339 A (GRANGROITH ET AL) 10 MARCH 1987	
A	US 4,636,772 A (YASUNAGA) 13 JANUARY 1987	
A	US 3,596,228 A (REED, JR. ET AL) 27 JULY 1971	
A	US 5,395,253 A (CRUMLY) 07 MARCH 1995.	
A	US 5,059,898 A (BARSOTTI ET AL) 22 OCTOBER 1991.	
A	US 4,975,638 A (EVANS ET AL) 04 DECEMBER 1990.	

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

\* Special categories of cited documents:

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\*O\* document referring to an oral disclosure, use, exhibition or other means

\*P\* document published prior to the international filing date but later than the priority date claimed

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\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

\*A\* document member of the same patent family

Date of the actual completion of the international search

14 AUGUST 1997

Date of mailing of the international search report

08 JAN 1998

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# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/08292

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,355, 079 A (EVANS ET AL) 11 OCTOBER 1994.	
A	US 5,521, 518 A (HIGGINS) 28 MAY 1996.	